Capture of Males of the Light Brown Apple Moth, *Epiphyas postvittana* (Walker), in Pheromone-Baited Delta Traps of Differing Size and Design

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Abstract. The light brown apple moth, *Epiphyas postvittana* (Walker), is a polyphagous pest first reported in California in 2006. State and federal agencies responded by initiating a large-scale trapping program to monitor its spread and population dynamics. The purpose of this study was to compare the trap catch between two delta traps differing in size and design. Both trap types were baited with female pheromone and trapped *E. postvittana* males on a sticky base. This insert was 121 cm^2 in the smaller Jackson traps compared to 360 cm^2 in the larger Scentry LP traps. In addition, the ends of the trap floor were folded upward (forming barriers) in the Scentry LP traps, whereas Jackson traps lacked such barriers. Working in San Francisco, I established 13 pairs of traps (one Jackson and one Scentry LP trap) and serviced them weekly during two separate 6-week intervals (June-August and September-October, 2008, respectively). Data for the Scentry LP traps showed that significantly more males were caught in September-October than in June-August, whereas captures in the Jackson traps were not significantly different between the early and late sampling periods. Correspondingly, numbers of males captured per trap per day were not statistically different between the two trap types in the early period but were significantly higher for the Scentry LP traps than the Jackson traps in the later period. Implications of these results for the ongoing detection and survey program are discussed.

Introduction

The light brown apple moth, *Epiphyas postvittana* (Walker), is a tortricid leafroller native to Australia and now established in New Zealand, New Caledonia, the British Isles, and Hawaii (Danthanarayana 1975). Larvae of this species are highly polyphagous and feed on more than 120 genera of plants in over 50 families (Geier and Briese 1981). The species poses a serious economic threat as host plants include numerous agriculturally important species, such as apple (*Malus domestica* Borkh), peach (*Prunus persica* (L.) Batsch), blackberry and raspberry (*Rubus* spp.), citrus (*Citrus* spp.), avocado (*Persea americana* Mill.), and grape (*Vitis vinifera* L.). The host range also includes many ornamentals (e.g., rose, *Rosa* spp.) and trees, such as oak (*Quercus* spp.), pine (*Pinus* spp.), willow (*Salix* spp.), and poplar (*Populus* spp.).

The light brown apple moth was first detected in the continental USA in 2006 when specimens were collected at a black light in Berkeley, California, and the USDA (United States Department of Agriculture) confirmed its presence in California based on specimens from Alameda and Contra Costa counties (Varela et al. 2008). The USDA and CDFA (California Department of Food and Agriculture) established a trapping program in the San Francisco area south to Santa Cruz and Monterey counties to determine the distribution, phenology, and abundance of *E. postvittana*. In the areas surveyed, Jackson traps baited with a synthetic blend resembling the female sex pheromone are placed at densities of roughly 5 traps/2.59 km^2 (5 traps per square mile) and scored weekly for male captures.

As documented for various moth species, the physical characteristics of traps may influence the numbers of target individuals captured (e.g., Valles et al. 1991, Reardon et al. 2006). Working with the light brown apple moth, Foster and Muggleston (1993) found that the field catch of males in pheromone-baited delta traps of varying size and design was positively related with trap length and width. For example, in delta traps lacking bottom barriers, the catch of male *E. postvittana* was positively correlated with trap size, i.e., the surface area of the sticky base. Based on additional observations in a wind tunnel, these authors concluded that the increase in field catch with increased trap length derived from the increased distance that males walked on the sticky surface toward the pheromone source. Foster and Muggleston (1993) also compared trap catch between similarly-sized delta traps either with or without bottom barriers and found that catch was significantly greater in traps containing a barrier. They proposed that, because of the barriers, males flew farther into the trap before landing and hence had a lower probability of exiting the trap.

The present study was undertaken at the behest of CDFA, who requested a comparative study of trap catch between two delta (triangular) traps of differing size and design, namely the smaller Jackson and the larger Scentry LP (Large Plastic) traps. As described below, the sampling period included a period of low and high moth abundance, respectively, and the comparative performance of the two trap types appeared to vary with moth population size. Implications of the present findings for monitoring the light brown apple moth are discussed.

Materials and Methods

Field work was conducted in the eastern end of Golden Gate Park, San Francisco. Lawns, manicured gardens, and small wooded areas are interspersed, and the majority of plants are exotic. Based on previous trapping by CDFA, Golden Gate Park was considered a "hotspot" for the light brown apple moth (http://www.cdfa.ca.gov/phpps/PDEP/lbam/lbam_counts.html).

The two delta-type traps used differed greatly in size. The length, width, and height (base to apex) of the Jackson traps were 12.7 cm, 9.5 cm, and 8.4 cm, respectively, and of the Scentry LP traps were 21.0 cm (with ends of the floor folded upward forming barriers 3.5 cm high), 19.5 cm, and 10.8 cm, respectively. Jackson traps have no option for bottom barriers and thus were completely "open". Because of the bottom barriers in the larger Scentry LP trap, the openings in this trap were only slightly larger than those in the Jackson traps (approximately 48 vs. 40 cm^2, respectively). The surface area of the sticky inserts placed in the bottom of the traps were 120.6 cm^2 (12.7 by 9.5 cm) for the Jackson traps and 360 cm^2 (20.0 by 18.0 cm) for the Scentry LP traps. Both trap types were completely white. The Jackson traps were made of thick, waxed paper, and the Scentry LP traps were made of a light plastic.

Thirteen pairs of traps—one Jackson and one Scentry LP trap—were established, and the same trapping locations were used over the entire study. Within a given pair, traps were separated by 17–45 m (average = 27.4 m, SE = 2.8, n = 13), and distances between nearest-neighbor pairs ranged from 77–310 m (mean = 152 m, SE = 17.3; n =13). Trapping was conducted during two distinct, 6-week intervals in 2008: June 24–August 5 and September 18–October 23. Average daily maximum and minimum temperatures during the earlier interval were 20.4°C and 12.7°C, respectively, and during the later interval were 22.4°C and 13.8°C, respectively. During both trapping periods, I alternated the location of the neighboring traps within pairs and replaced sticky inserts at weekly intervals. At the start of both trapping periods, a gray rubber septum containing synthetic female pheromone (3 mg of a 94:6 ratio of (E)-11-tetradecenyl acetate, ((E)-11-14:OAc), and (E,E)-(9,11)-tetradecadienyl acetate ((E,E)-9,11-14:OAc); Bellas et al. 1983) was placed in the center of the sticky insert

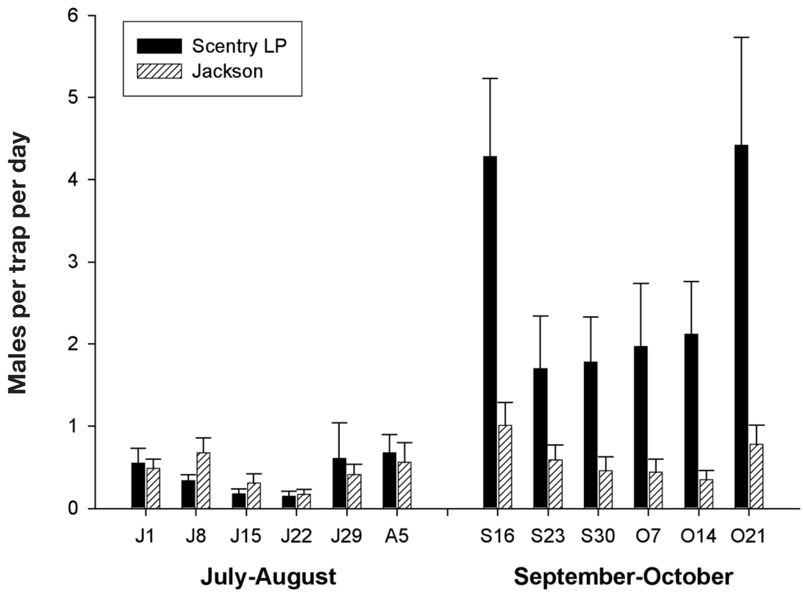

Figure 1. Captures of *Epiphyas postvittana* males in pheromone-baited Scentry LP or Jackson traps in Golden Gate Park, San Francisco. Bar heights represent weekly means ($\pm$ 1 SE, n = 13 traps per type); the letter-number combinations along the abscissa designate month and day of trap scoring.

of each trap and was not replaced over the 6-week period (i.e., it was transferred weekly to the center of a new sticky insert). According to National Survey Guidelines for the light brown apple moth (http://www.aphis.usda.gov/plant_health/plant_pest_info/lba_moth/downloads/lbam-natlsurveyguidelines.pdf), the pheromone is attractive over a 6-week interval. Traps were placed at 2–3 m above ground on various tree species, with the majority on oaks, pines, or eucalyptus. Only 1–2 non-target insects were captured each week, and the majority of these were wasps and honey bees. The few non-target moths captured were easily distinguished from *E. postvittana* by their stouter body and larger size.

Neither raw nor log transformed data met the assumptions of parametric statistical tests, consequently the non-parametric Mann-Whitney test was used for pair wise comparisons.

Results

Based on data pooled from both trap types, the number of males captured in the September–October period was significantly greater than that captured in the June-August period (mean values of males/trap/day: 1.56 vs. 0.52 for late vs. early periods, respectively; $T = 26{,}632$, $n_1 = n_2 = 156$, $P = 0.005$). Data for the Scentry LP traps alone showed the same trend: mean numbers of males/trap/day were 2.71 and 0.42 for the late and early periods, respectively ($T = 4314$, $n_1 = n_2 = 78$, $P < 0.001$, Fig. 1). In the Jackson traps, however, the difference in male captures between September-October and June-August was not statistically significant (mean values of males/trap/day: 0.60 and 0.44, respectively; $T = 5842$, $n_1 = n_2 = 78$, $P = 0.32$, Fig. 1).

As the preceding analyses suggest, the comparative performance of the two trap types differed between the two sampling periods. During the early sampling period, there was no difference in the number of males captured per trap per day between the Scentry LP and Jackson traps ($T = 5782$, $n_1 = n_2 = 78$, $P = 0.23$). Additionally, the proportion of "no captures" (i.e., zeros for a given week) was similar between the Scentry LP (25/78 = 32%) and Jackson (20/78 = 26%) traps during the early sampling period ($\chi^2 = 0.5$, df = 1, $P = 0.48$).

In contrast, the performance of the two trap types differed substantially during the late sampling period. On average, the Scentry LP traps captured a significantly higher number of males than the Jackson traps during September–October ($T = 7578$, $n_1 = n_2 = 78$, $P < 0.001$). Also, during the late sampling period, the proportion of no captures for the Scentry LP traps (8/78 = 10%) was significantly lower than that recorded for the Jackson traps (19/59 = 32%; $\chi^2 = 4.5$, df = 1, $P = 0.03$). For the Scentry LP traps, the proportion of no captures was significantly lower in the late period than the early period ($\chi^2 = 5.7$, df = 1, $P = 0.02$), whereas no such difference was detected for the Jackson traps ($\chi^2 = 0$, df = 1, $P = 1.0$).

Discussion

The total number of *E. postvittana* males trapped increased significantly between the June-August and September-October sampling periods. Among insects, trap catch and population density are often positive correlated (Zhang et al. 2005, Jactel et al. 2006), but a number of studies have reported no relationship between these parameters (Roltsch and Mayse 1984, Shepherd et al. 1985). Consequently, whether the increased trap catch observed here between early and late sampling periods reflected an actual increase in the population density remains unknown. For example, the slightly higher temperatures of the late period may have resulted in increased flight activity of the moths and hence increased trap catch independently of population size. However, trapping data collected in the San Francisco area south to Monterey showed an area-wide peak in male captures in September–October in both 2007 and 2008 (http://www.cdfa.ca.gov/phpps/PDEP/lbam/situationreports.html). Data on this website show that, for San Francisco County, nearly twice as many *E. postvittana* males were captured in September–October, 2008, than in June–August, 2008. Given these trends, it appears reasonable to assume that the local population of *E. postvittana* in Golden Gate Park increased in size between the early and late study intervals.

Based on this assumption, the relationship between trap catch and moth population size appeared to vary between the two trap types examined. For the Jackson traps, both the number of males captured per trap per day and the incidence of zero captures (over weekly sampling intervals) appeared to be independent of population size. In contrast, the Scentry LP traps caught more males per trap per day and were more likely to capture at least one male per week as the population increased in size. Thus, the two trap types seemed to perform similarly at lower moth density, but the Scentry LP traps appeared to capture more males than the Jackson traps at higher moth density.

Such density-dependent variation in the relative performance of different trap types has been described previously for other Lepidoptera. Several studies (Herbert et al. 1991, Delisle et al. 1998) have shown that pheromone-baited traps outperform light traps at low moth density while the opposite holds for high moth density. More germane to the present study, comparisons between different pheromone-baited trap types have also revealed a density-dependent relationship in relative trap performance. For example, similar to the present study, Tamhankar et al. (2001) reported that two different traps, Delta and Omnidirectional, containing the same dose of pheromone caught similar numbers of adult males of the cotton pink bollworm, *Pectinophora gossypiella* (Saunders), at low density but that

the Omnidirectional traps caught more than twice as many males as the Delta traps at high density. Similarly, Evenden et al. (1995) found that, at a pheromone dose of 1 μg, Unitraps and sticky traps caught similar numbers of male western hemlock loopers, *Lambdina fiscellaria lugubrosa* (Hulst) when moth density was low but that Unitraps captured about 10 times as many moths as sticky traps at high moth density. These examples show simply that the relation between population density and trap catch may vary even within the same trap type. The factor(s) responsible for this observation is generally unknown and may, of course, differ among different studies.

In conclusion, the present study suggests that the Scentry LP trap is as effective as the Jackson trap at detecting *E. postvittana* at low population size and more effective than the Jackson trap at monitoring changes in population size. This result suggests, in turn, that the trapping program in the San Francisco area would generate more accurate data on the population dynamics of the light brown apple moth if Scentry LP traps were used instead of Jackson traps. However, two additional factors should be considered. First, Scentry LP traps are more expensive than Jackson traps. The approximate cost of a single Scentry LP trap is $3.90 (body and insert) compared to only $0.60 for a Jackson trap (body, insert, and hanger), although the greater durability and longevity of Scentry LP traps may offset this cost difference. In addition, the Scentry LP traps are more conspicuous in the habitat than the smaller Jackson traps. Scentry LP traps are thus more likely to be tampered with or stolen, which would both interfere with data collection and necessitate trap replacement with associated cost.

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